

This contention is traversed, as follows:

At page 9, lines 5-9, of the present specification, it is noted that one object of the present invention is to eliminate the problem of peeling of the ferroelectric capacitor insulation film, which is caused by oxidation of the Ti atoms that have migrated through the lower electrode and reached the surface thereof. See also page 11, lines 3-24 at which it is noted that the claimed compositional range of the atmosphere is particularly effective for achieving the stated object. One or more of these distinguishing features are present in each independent claim now pending in the present case, as is discussed in more detail below relative to each independent claim and related dependent claims.

A. Claims 12, 14 and 21-28 are Patentably Distinguishable over the Combination of *Chu*, *Cuchiari* and *Izuha*.

To underscore the significance of these features of the present invention, claims 12, 14 and 21 have been amended to clearly recite that there is a layer containing Ti underneath the lower electrode.

As amended, claims 12, 14 and 21 are not suggested by *Chu* even when combined with *Cuchiari* and *Izuha*, because *Chu*, *Cuchiari* and *Izuha* are silent regarding the claimed role of Ti. Thus, the subject matter as set forth in amended claims 12, 14 and 21 cannot be derived from the prior art. Claims 12, 14, and 21 are therefore patentably distinguishable over the combination of references. Withdrawal of the rejection of claims 12, 14, and 21 is thus believed proper and respectfully requested.

In addition, claims 22-28 contain the distinguishing features of independent claim 21 discussed above, through their dependency thereon. Thus, dependent claims 22-28 are allowable as depending from allowable base claim. Withdrawal of the § 103 rejection of claims 22-28 is respectfully requested.

B. Claims 1, 2, 4-11 and 13 are Patentably Distinguishable over the Combination of *Chu*, *Cuchiari* and *Izuha*.

Claim 1 has been amended to more properly claim the feature of the present invention that the PZT film undergoes a single crystallization anneal in

an atmosphere having a composition of 1 to 20% volume fraction of O<sub>2</sub>. In contrast, *Chu* teaches a two-step annealing process.

In the process of *Chu*, which relies on the existence of large numbers of O<sub>2</sub> vacancies in the PZT film for securing the effective paths of lead cation migration, a second annealing process in the O<sub>2</sub> atmosphere must be conducted to compensate for the oxygen defects. In contrast, amended claim 1 recites a crystallization process which is conducted in a single step annealing process in an atmosphere of 1 to 20% O<sub>2</sub>, and therefore the second annealing process can be eliminated.

Because *Cuchiaro* and *Izuha* are also silent with regard to a single crystallization anneal as now claimed, claim 1 and dependent claims 2, 4-11 and 13 are patentably distinguishable over the references of record, and withdrawal of the § 103 rejection of claims 1, 2, 4-11 and 13 is respectfully requested.

C. Claims 15-19 are Patentably Distinguishable over the Combination of *Chu*, *Cuchiaro* and *Izuha*.

Claim 15 has been amended to claim the orientation of the PZT crystal grains in addition to the other claim limitations. More specifically, amended claim 15 recites the preferential alignment in the <111> orientation for the crystal grains in the PZT film.

In contrast, *Izuha* teaches a ferroelectric crystal which is "BST" [(Ba, Sr)TiO<sub>3</sub>], not PZT as claimed. Ferroelectric BST crystal has a tetragonal crystal structure and is believed to have grown generally in the <001> orientation. At column 9, line 43 of *Izuha* it is noted that the lower electrode of SrRuO<sub>3</sub> is oriented in the c-axis direction, and hence in the <001> orientation. *Izuha* then describes that it is difficult to distinguish the boundary between each layer (column 11, lines 47-49). There is no teaching in *Izuha* to control the growth of the BST crystals in the <111> orientation as is now set forth in amended claim 15.

Indeed, in a ferroelectric crystal of perovskite structure, it is ideal to grow the perovskite crystal in the <001> orientation for maximizing the ferroelectric response. In the case of a PZT film crystallized from an

amorphous film, on the other hand, it is difficult to achieve the preferential growth in the <001> orientation. When such an attempt is made, a growth in the <100> direction also tends to occur in substantially the same proportion. In the <100> orientation, the perovskite shows no ferroelectric response.

While *Chu* teaches the <111> orientation for the PZT film, there is no motivation for a person skilled in the art to combine the teaching of *Chu* with the teachings of *Izuha*. Indeed, the combination of *Chu* with *Izuha* is not physically possible because of the difference of the material systems. In addition, *Chu* fails to teach a PZT film having a columnar microstructure and a substantially uniform grain diameter of 200nm or less. *Cuchiario* does not supply the teachings in which *Chu* and *Izuha* are deficient because *Cuchiario* is silent about the crystal orientation of the PZT film.

Accordingly, claim 15 and dependent claims 16-19 are patentably distinguishable over the combination of references upon which the § 103(a) rejection is based. Withdrawal of the rejection of claims 15-19 is thus proper and respectfully requested.


D. Conclusion.

For the reasons given above, all pending claims 1, 2, 4-12, 14-19 and 21-28 are now believed to be in form for allowance and such action is respectfully requested. Should any issues remain, the Examiner is kindly asked to telephone the undersigned.

Although no fee are believed due for this filing, please charge Deposit Account No. 50-1123 any fee deficiency associated herewith.

Respectfully submitted,

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MARKED-UP COPY OF AMENDED CLAIMS

1. (Four Times Amended) A method of fabricating a semiconductor device having a ferroelectric capacitor, comprising the steps of:

forming an active device element on a substrate;

forming an insulation film over said substrate to cover said active device element;

forming a lower electrode layer of said ferroelectric capacitor over said insulation film;

forming an amorphous PZT ferroelectric film on said lower electrode layer as a capacitor insulation film of said ferroelectric capacitor in the form of an amorphous film;

[crystallizing said amorphous PZT ferroelectric film by applying a thermal annealing process in an atmosphere containing a non oxidizing gas and an oxidizing gas;] and

forming an upper electrode layer on said PZT ferroelectric film, wherein said step of [crystallizing] forming said PZT ferroelectric film comprises a single annealing step, conducted after the step of depositing said PZT ferroelectric film, for crystallizing said PZT ferroelectric film, said single annealing step being [is] conducted in an atmosphere having a [by setting the] composition [of said atmosphere] set such that said atmosphere contains [said] an oxidizing gas with a fraction of 1 to 20% in volume.

12. (Twice Amended) A method of fabricating a semiconductor device having a ferroelectric capacitor, comprising the steps of:

forming an active device element on a substrate;

forming an insulation film over said substrate to cover said active device element;

forming a lower electrode layer of said ferroelectric capacitor over said insulation film, such that said lower electrode is formed on a layer containing Ti;

forming a ferroelectric film on said lower electrode as a capacitor insulation film of said ferroelectric capacitor;

crystallizing said ferroelectric film by applying a thermal annealing process in an O<sub>2</sub> atmosphere under a reduced total pressure in the range between 1 Torr and 40 Torr; and

forming an upper electrode layer on said ferroelectric film.

14. (Twice Amended) A method of fabricating a semiconductor device having a ferroelectric capacitor, comprising the steps of:

forming an active device element on a substrate;

forming an insulation film over said substrate to cover said active device element;

forming a lower electrode layer of said ferroelectric capacitor over said insulation film, said lower electrode layer [including] being formed on a layer [part] containing Ti atoms;

forming a ferroelectric film on said lower electrode layer as a capacitor insulation film of said ferroelectric capacitor;

crystallizing said ferroelectric film by applying a thermal annealing process in an atmosphere of an oxidizing gas with a fraction of 1 to 20% in volume; and

forming an upper electrode layer on said ferroelectric film, wherein said step of crystallizing said ferroelectric film is conducted by supplying O<sub>2</sub> controlled to cause an oxidation in said Ti atoms reached a surface of said lower electrode from said layer part containing Ti atoms.

15. (Four Times Amended) A semiconductor device, comprising:  
a substrate;

an active device element formed on said substrate;

an insulation film provided over said substrate to cover said active device element;

a lower electrode containing Pt provided over said insulation film;

a PZT ferroelectric film provided on said lower electrode, said PZT ferroelectric film having a columnar microstructure extending from an interface between said lower electrode and said PZT ferroelectric film in a direction substantially perpendicular to a principal surface of said lower electrode, said PZT ferroelectric film generally having a <111> orientation and consisting of

crystal grains generally having said <111> orientation and a substantially uniform grain diameter of less than about 200nm; and  
an upper electrode provided on said PZT ferroelectric film.

21. (Thrice Amended) A method of fabricating a semiconductor device having a ferroelectric capacitor, comprising the steps of:

forming an active device element on a substrate;

forming an insulation film over said substrate to cover said active device element;

forming a lower electrode layer of said ferroelectric capacitor over said insulation film such that said lower electrode is formed on a layer containing Ti;

forming an amorphous PZT ferroelectric film on said lower electrode layer as a capacitor insulation film of said ferroelectric capacitor in the form of an amorphous film;

crystallizing said amorphous PZT ferroelectric film by applying a thermal annealing process in an atmosphere containing a non-oxidizing gas and an oxidizing gas; and

forming an upper electrode layer on said PZT ferroelectric film, wherein said step of crystallizing said PZT ferroelectric film is conducted by setting the composition of said atmosphere such that said atmosphere contains said oxidizing gas with a fraction of 1 – 20% by volume, and wherein said method further comprises the step, after said step of crystallizing said PZT ferroelectric film, of oxidizing said ferroelectric film in an oxidizing atmosphere.